Big Idea 4: Interactions

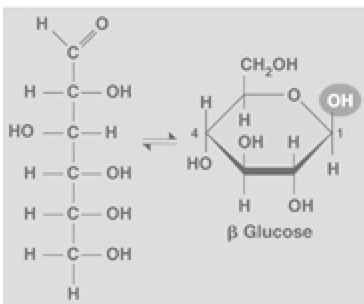
4.1– **Interactions** within biological systems lead to complex properties

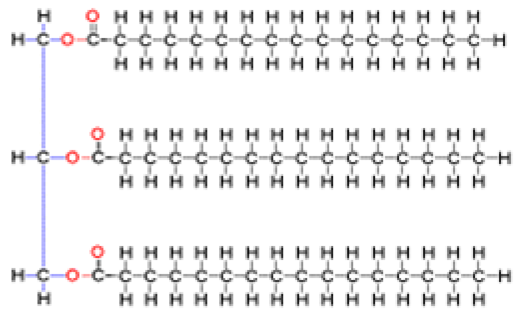
Biological Systems

- Atoms
- Molecules
- Organelles
- Cells
- Organs
- Organ Systems
- Individuals
- Populations
- Communities
- Ecosystems

Molecule Properties

- Atoms interact to form molecules
  - Carbon, Nitrogen, Phosphorous, Oxygen, Hydrogen, Sulfur
- Sequence & location are significant
  - Differences between a carbohydrate & fat





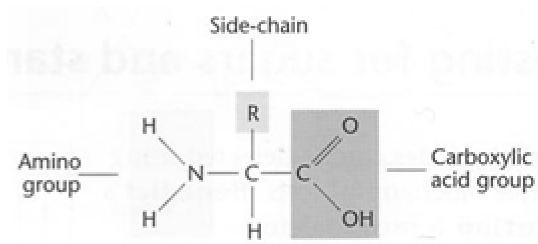
Structure & function depends on monomers & their assembly!

1. Nucleic Acids

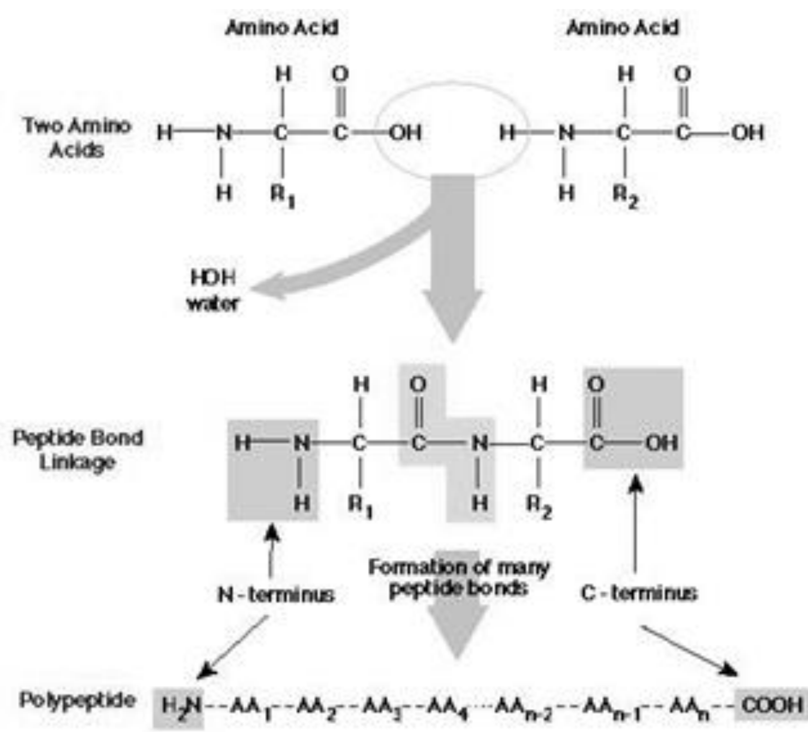
- Nucleic Acid Type
  - RNA vs. DNA?
- Structure suits function
  - RNA vs. DNA?
- Directionality alters function
  - 5' end vs. 3' end?

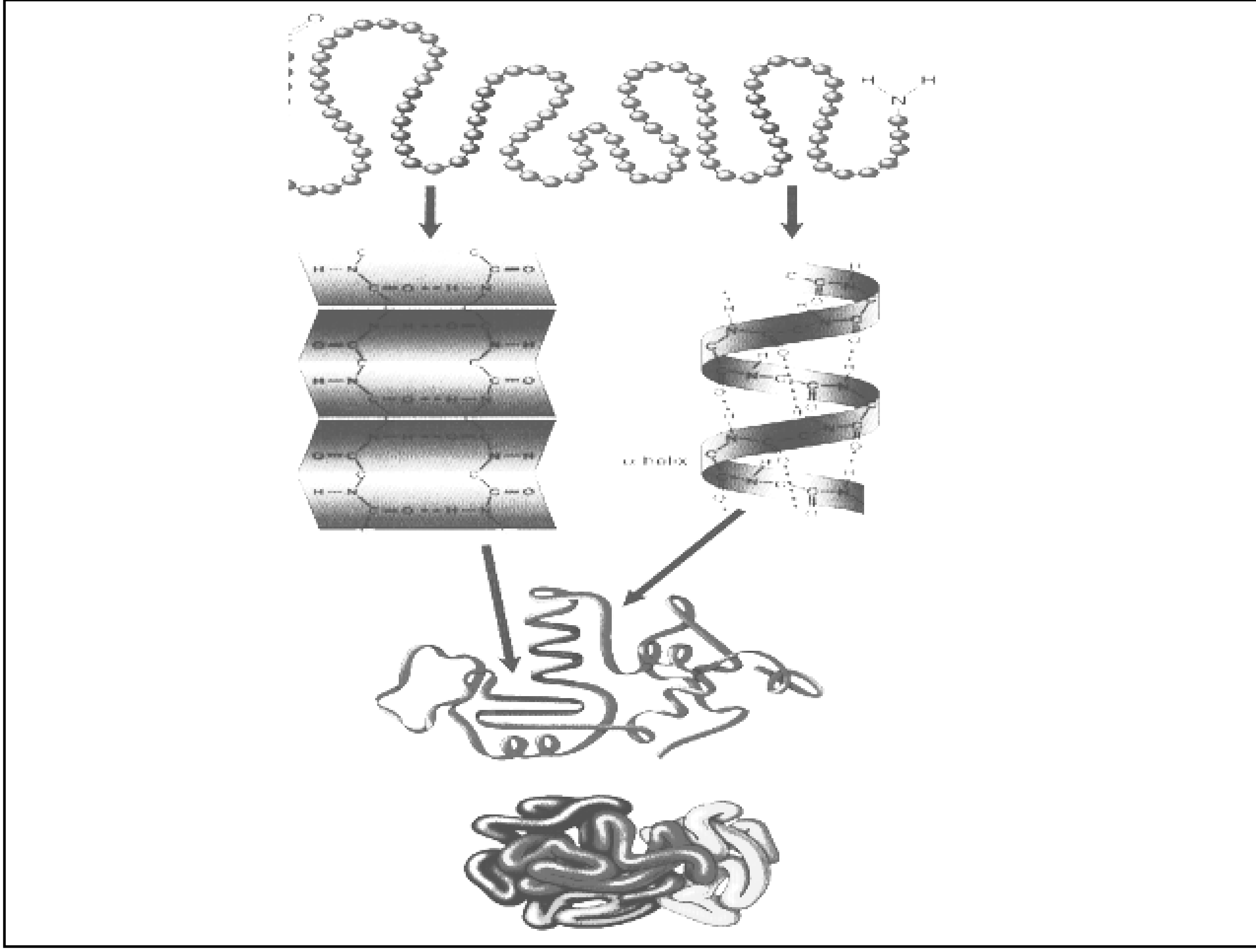
2. Proteins

- Amino acid interactions depend on structure
  - Hydrophilic, Hydrophobic, Ionic (R-Group)
- Sequence of amino acids leads to different functions & interaction capabilities.



2. Proteins: Directionality – NH_2 vs. COOH ends





Primary Structure

- Peptide bonds
- Linear sequence of AA’s

Secondary Structure

- Hydrogen Bonds
- Twists & Folds of the sequence

Tertiary Structure

- R-Group interactions
- ionic, hydrophobic, etc.

Quaternary Structure

- 2+ polypeptides interacting

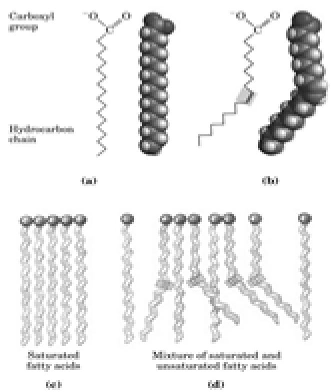
3. Lipids

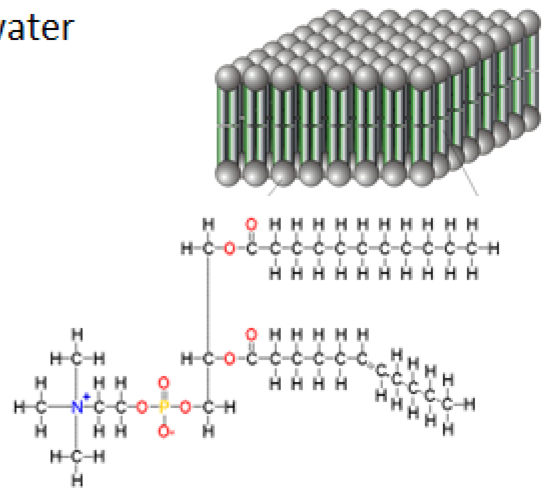
Non-polar and interact with other non-polars.

Phospholipids have polar regions!

Interact with water

Fatty Acid Structure

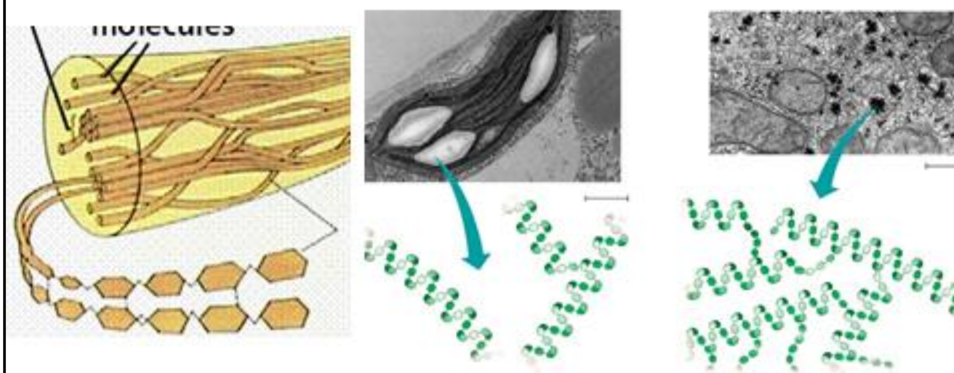


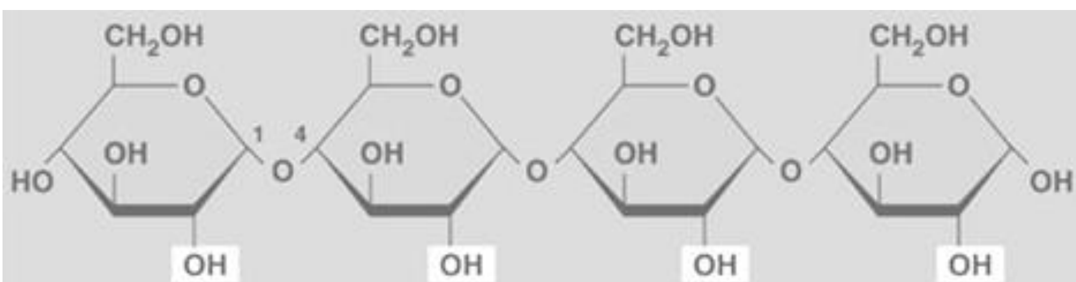


4. Carbohydrates

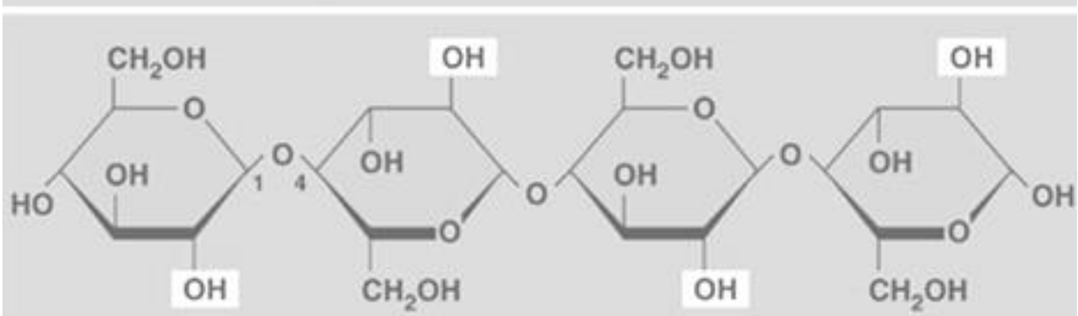
Different monosaccharides & linkages lead to diversity of compounds.

Form also by dehydration synthesis reactions.





(b) Starch: 1–4 linkage of α glucose monomers



(c) Cellulose: 1–4 linkage of β glucose monomers

Subcellular Components

- The structure & function of subcellular components, and their interactions, provide essential cellular processes.
- Examples:
  - Mitochondria and peroxisomes
  - Mitochondria & Chloroplasts
  - ER & Ribosomes
  - ER & Vacuoles

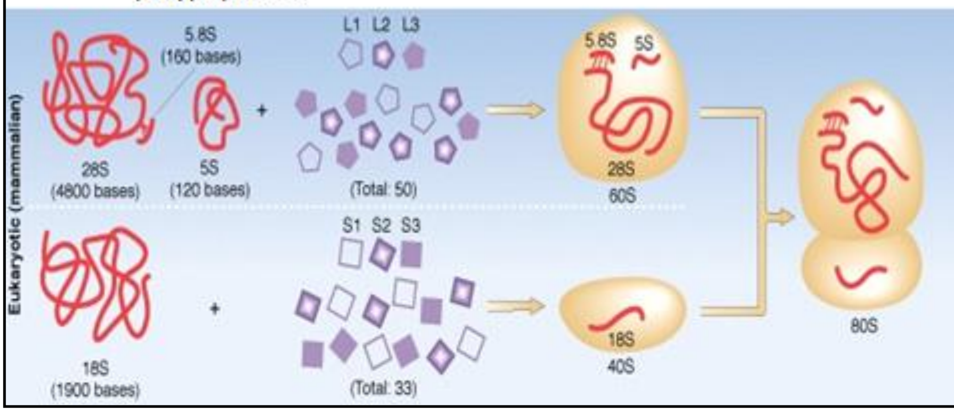
1. Ribosomes

a. Small, universal structures

b. 2 interacting parts: rRNA & Protein

c. Interact to become sites of protein synthesis

d. Translation of genetic information yields specific polypeptides.



1. Ribosomes

e. Can be “free” or “attached”

f. **Free** ribosomes are in the cytosol and produce proteins that will **remain** in the cytosol.

- Glycolysis enzymes – Actin of cytoskeleton

g. **Attached** ribosomes are embedded in the Rough ER membranes. These protein products will be **secreted** out of the cell OR become **embedded** in the plasma membrane.

- Sebum of sweat glands
- Membrane receptor proteins

2. Endoplasmic Reticulum

a. 2 forms, Rough & Smooth

b. Rough ER:

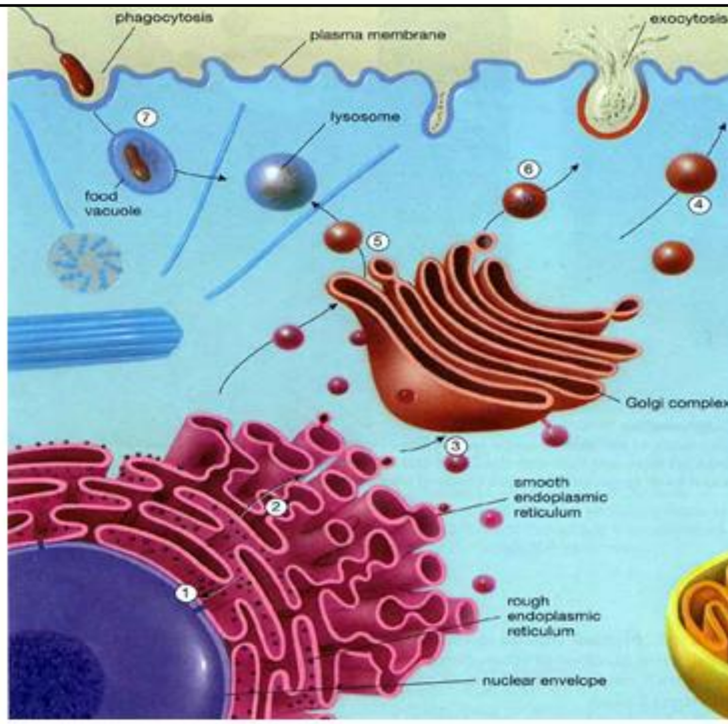
1. Compartmentalizes cell
2. Provides mechanical support
3. Intracellular Transport
4. Protein synthesis

c. Smooth ER:

1. Synthesizes Lipids

3. Golgi Complex

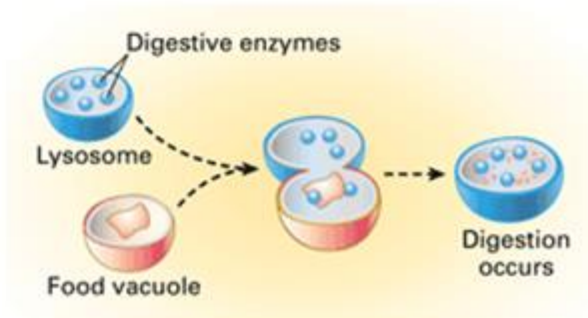
a. Series of flattened membrane sacs (cisternae)
b. Synthesize & Package small molecules for transport in vesicles.
c. Produce Lysosomes.


phagocytosis
plasma membrane
exocytosis
7
lysosome
food
vacuole
6
4
5
Golgi complex
3
smooth
endoplasmic
reticulum
2
1
rough
endoplasmic
reticulum
nuclear envelope

4. Lysosomes

a. Membranous sacs containing hydrolytic enzymes important for:

1. Intracellular digestion
2. Apoptosis
3. Recycling of organic materials



5. Vacuoles

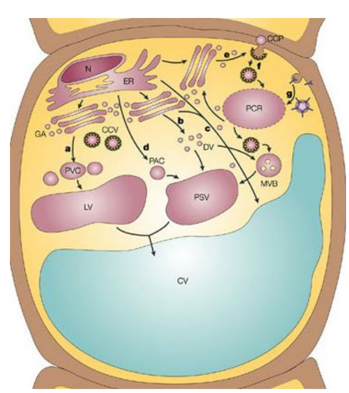
a. Membranous sacs

b. Intracellular digestion

c. Release waste products.

d. Plant vacuoles: Variety of functions

1. Pigment storage
2. Cell growth
3. Containing toxins
4. Large SA/V ratio

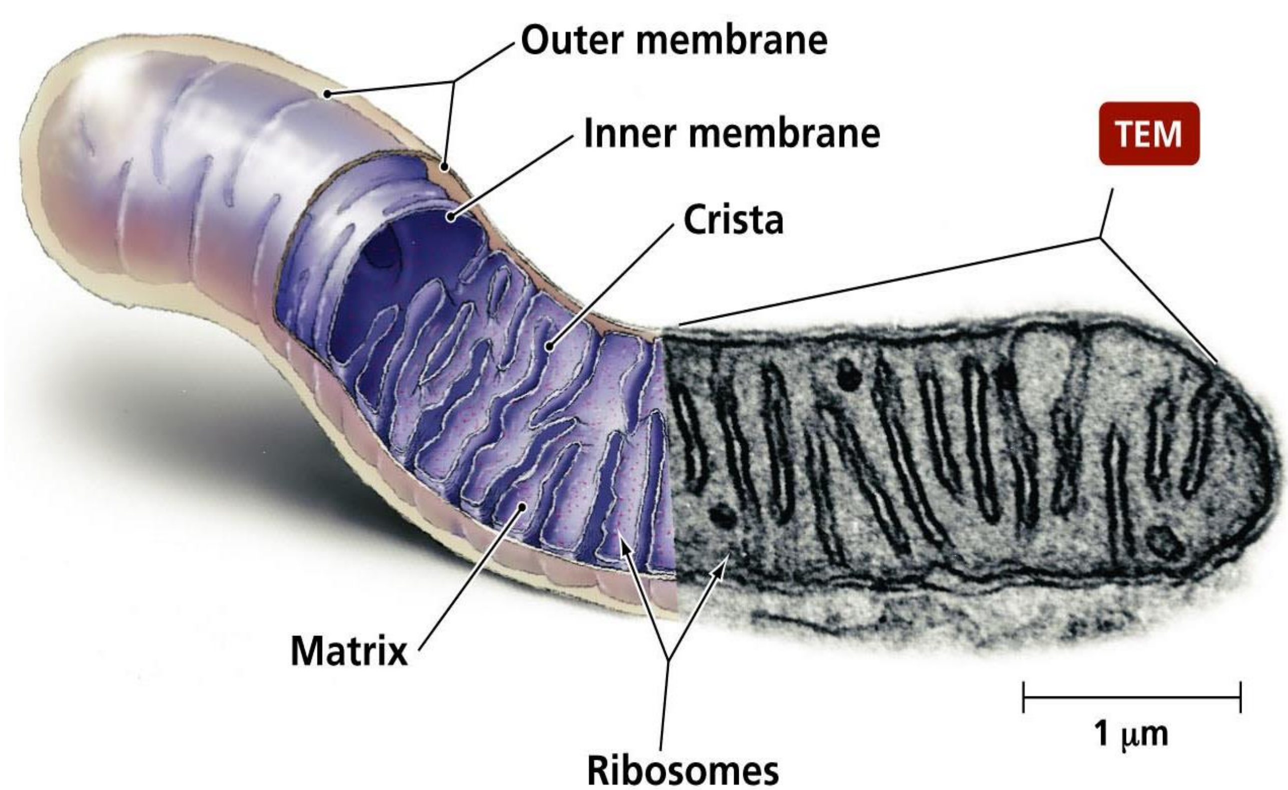


6. Mitochondria

a. Energy capture & transformation

b. Double-membrane allowing for compartmentalization that is inherent to its function.

c. Smooth outer membrane, folded inner membrane (cristae) containing enzymes for ATP production. Folds increase surface area!



7. Chloroplasts

a. Algae & Plants

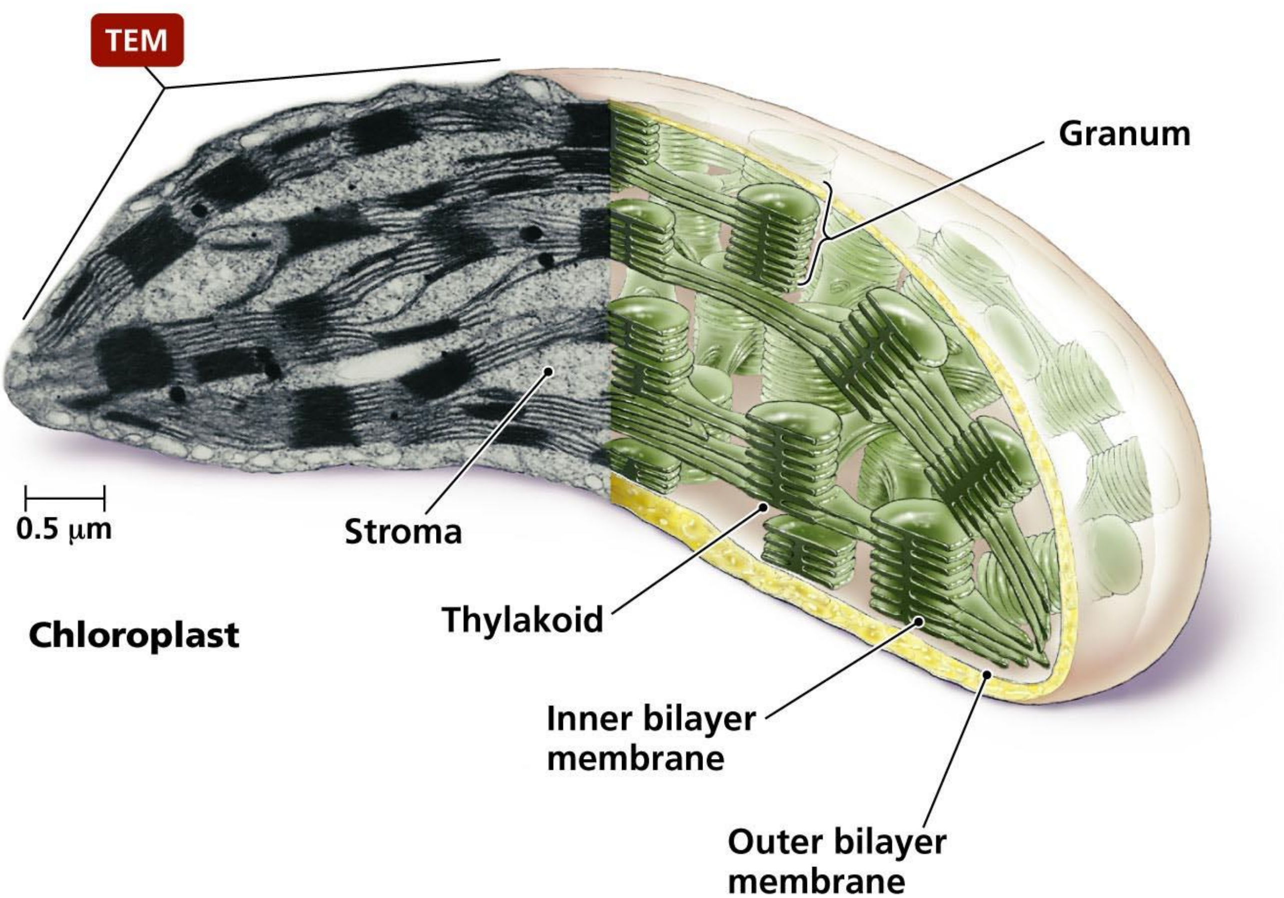
b. Photosynthesis

c. Capture energy in sunlight and convert into chemical bond energy (sugars).

d. A variety of Chlorophylls, but "*a*" primarily

e. Double-membrane compartmentalizes functions.

f. Thylakoids in groups called grana that produce ATP & NADPH, used to power the Calvin Cycle in the stroma, where CO_2 is converted into sugars.



Organ Interactions

- Interactions & coordination between organs provide essential biological activities.
  - Roots, stems, leaves
  - Stomach, small intestine, pancreas

Organ System Interactions

- Interactions between organ systems provide essential biological activities.
  - Respiratory & Circulatory
  - Nervous & Muscular

Population Dynamics

- In order to understand interactions within ecosystems, each population must be understood
  - Size
  - Density
  - Dispersion Patterns
  - Limiting Factors
  - Life Histories (reproductive cycle)

Population Dynamics

Population: all the individuals of a species that live together in an area

Demography: the statistical study of populations, make predictions about how a population will change

Key Features of Populations

1. Size: number of individuals in an area

Population Growth Rate in a time interval: Birth Rate (natality) - Death Rate (mortality)

How many individuals are born vs. how many die

Population Growth Rate (*r*) = Birth rate (*b*) – death rate (*d*)

$$r = b - d$$

Also shown as

$$dN/dt = B-D$$

If no other information is given, this is how we determine a change in a population.

Other factors such as emigration & immigration also affect the size & density.

Key Features of Populations

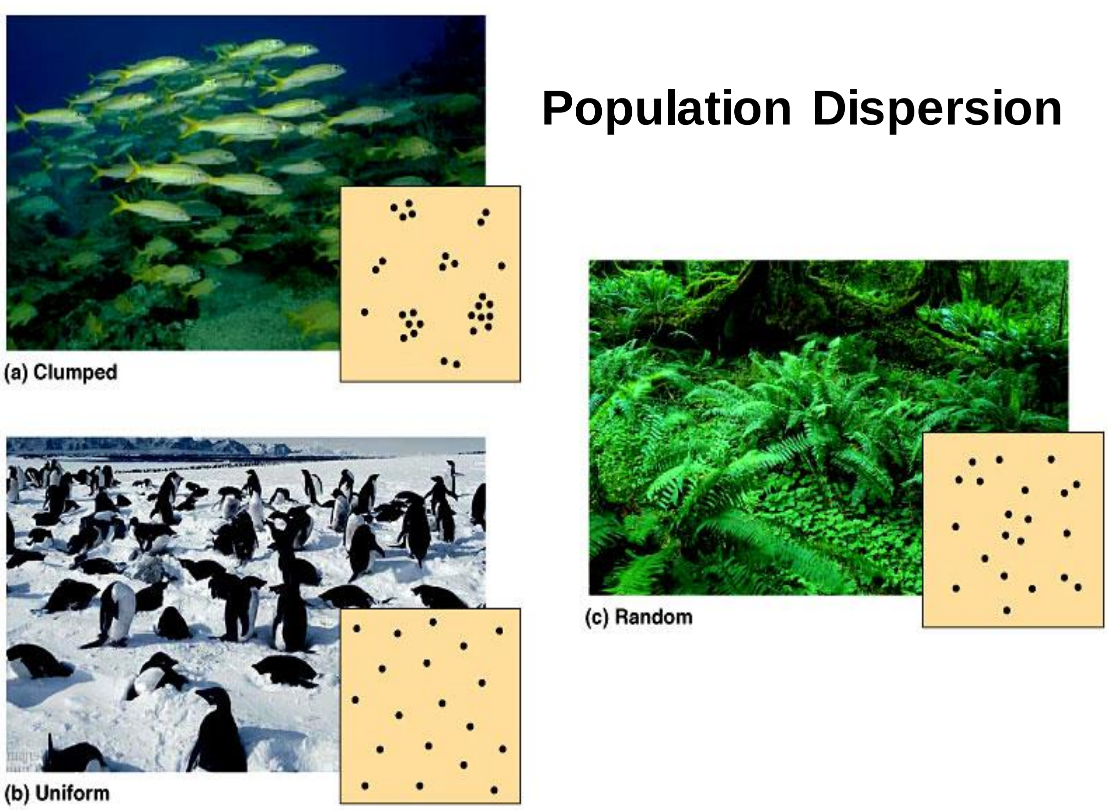
2. Density: measurement of population per unit area or unit volume

Formula: $D_p = \frac{N}{S}$

Pop. Density = # of individuals ÷ unit of space

Size measures the total population whereas density is more concerned with the average number of individuals that could be found per unit of space (acre, hectare, etc.)

Population Dispersion



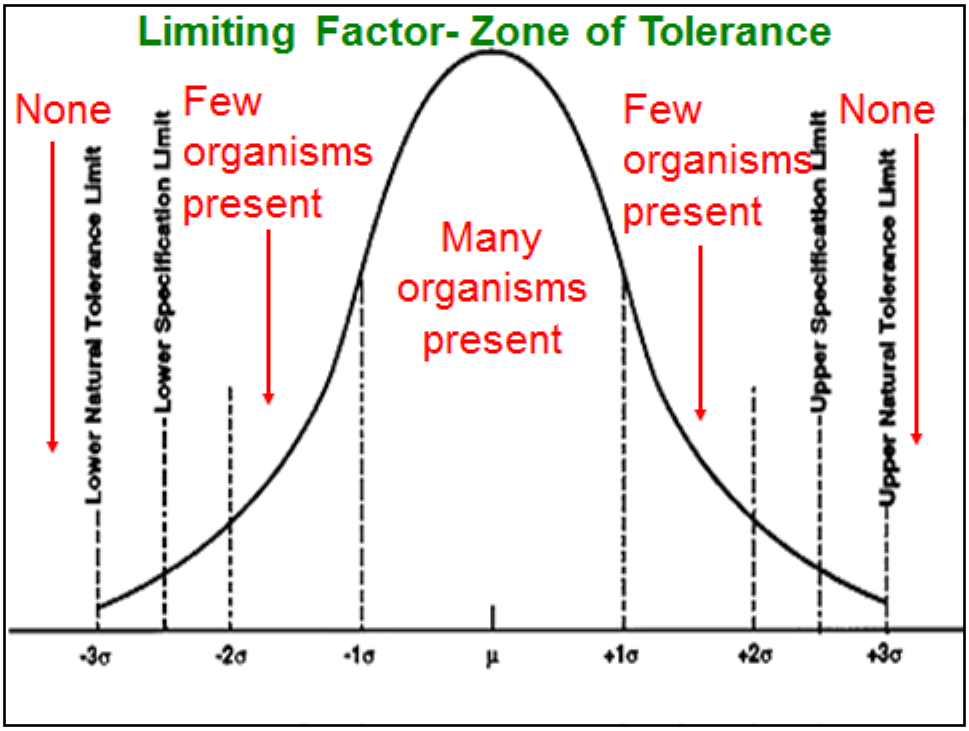
Other Factors that affect density

1. **Density-dependent factors-** Biotic factors in the environment that have an increasing effect as population size increases

Ex. disease
competition
parasites

2. **Density-independent factors-** Abiotic factors in the environment that affect populations regardless of their density

Ex. temperature
storms
habitat destruction
drought



Limiting factor- **any biotic or abiotic factor that restricts the existence of organisms in a specific environment.**

EX.- **Amount of water**

Amount of food

Temperature

Growth Models

- Exponential Growth – Assumes no limits on resources, no competition, no predation
- $\Delta N/\Delta t = r_{max}N$

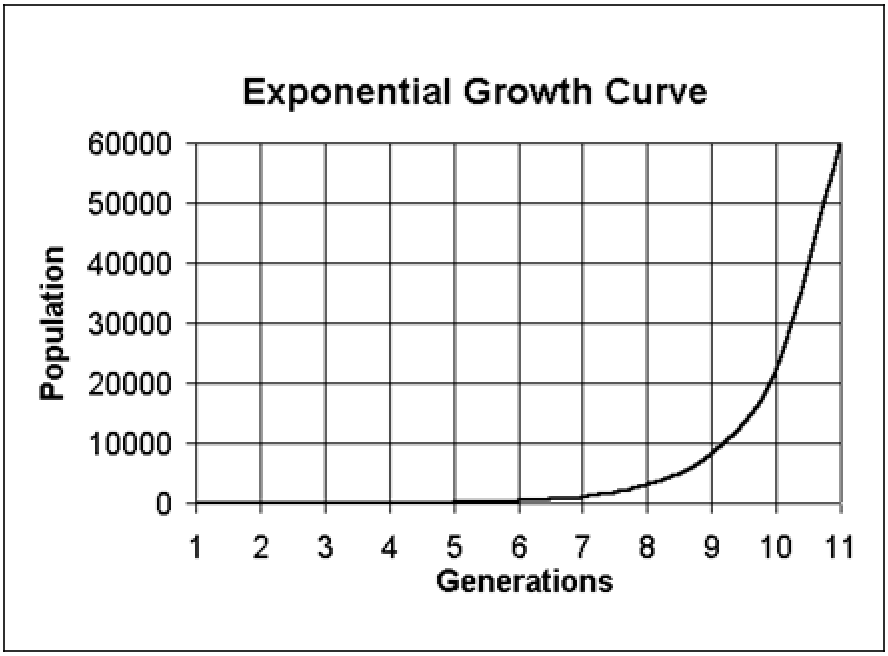
$r_{max} = 0.5$

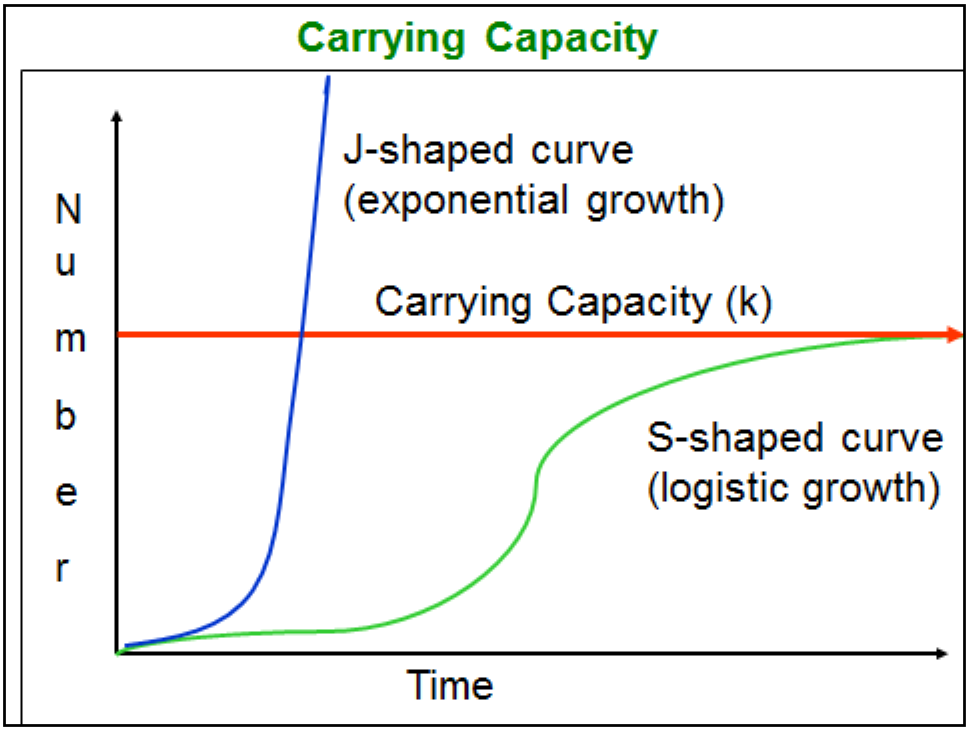
year	0	1	2	3	4	5	6	7	8	9
N	50	75	113	169	253	380	570	855	1283	1924

r_{max} is the per capita (average per individual) rate of growth and is calculated by dividing the # births minus the # deaths and any changes due to immigration/emigration by the population size.

N Is the population size

dN/dt is the overall population growth rate (as compared to the per-capita growth rate concerning an individual)


Exponential Growth Curve
Population
60000
50000
40000
30000
20000
10000
0
1
2
3
4
5
6
7
8
9
10
11
Generations



Carrying Capacity- (K) the maximum population size that can be supported by the available resources

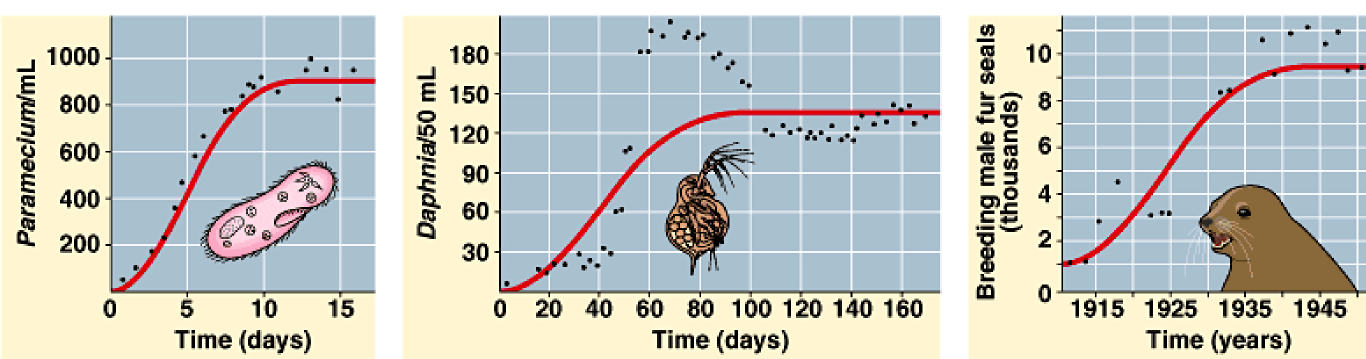
There can only be as many organisms as the environmental resources can support

Number varies on environment/species

Growth Models

- Logistic Growth: Factors in carrying capacity (K)
- K = 1000

Population Size: N	Intrinsic Rate of Increase: r_{max}	$\left(\frac{K-N}{K}\right)$	Per Capita Growth Rate: $r_{max}\left(\frac{K-N}{K}\right)$	Population Growth Rate:* $r_{max}N\left(\frac{K-N}{K}\right)$
20	0.05	0.98	0.049	+1
100	0.05	0.90	0.045	+5

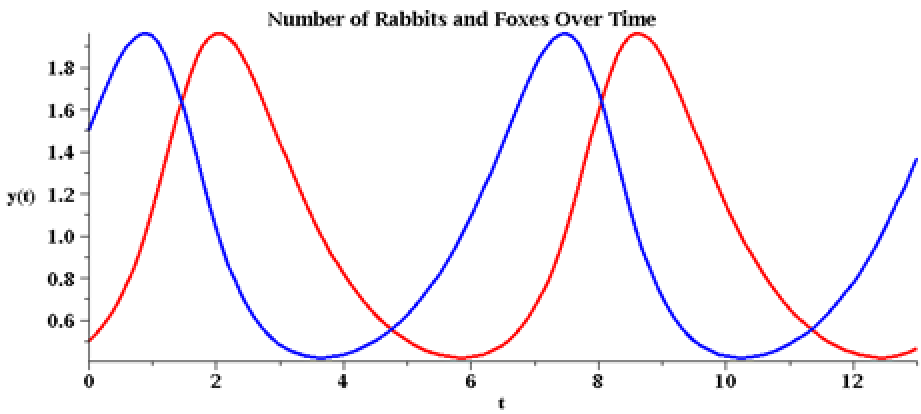


(a) A *Paramecium* population in laboratory culture

(b) A *Daphnia* population in laboratory culture

(c) A fur seal (*Callorhinus ursinus*) population on St. Paul Island, Alaska

- Mathematical & Computer models can illustrate & investigate impacts of changes in a population and/or community.
  - Predator/prey spreadsheet models
  - Global climate change models

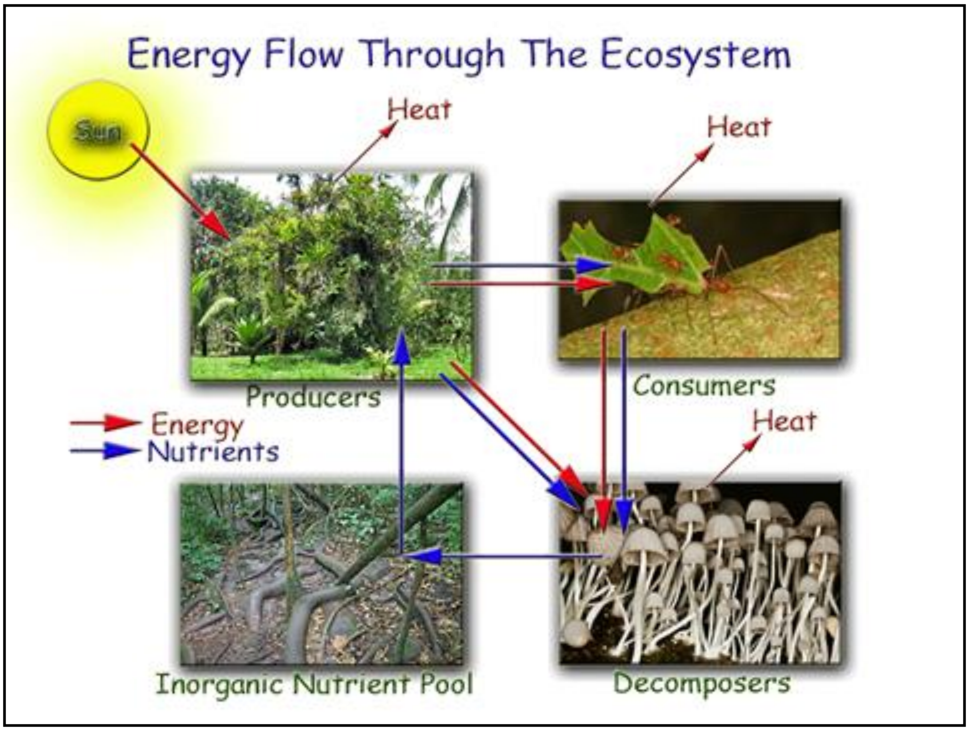


2 Life History Patterns

- 1. r-selection
  - short life span
  - small body size
  - reproduce quickly
  - have many young
  - little parental care
  - Ex: cockroaches, weeds, bacteria

2 Life History Patterns

- 2. K-selection
  - long life span
  - large body size
  - reproduce slowly
  - have few young
  - provides parental care
  - Ex: humans, elephants



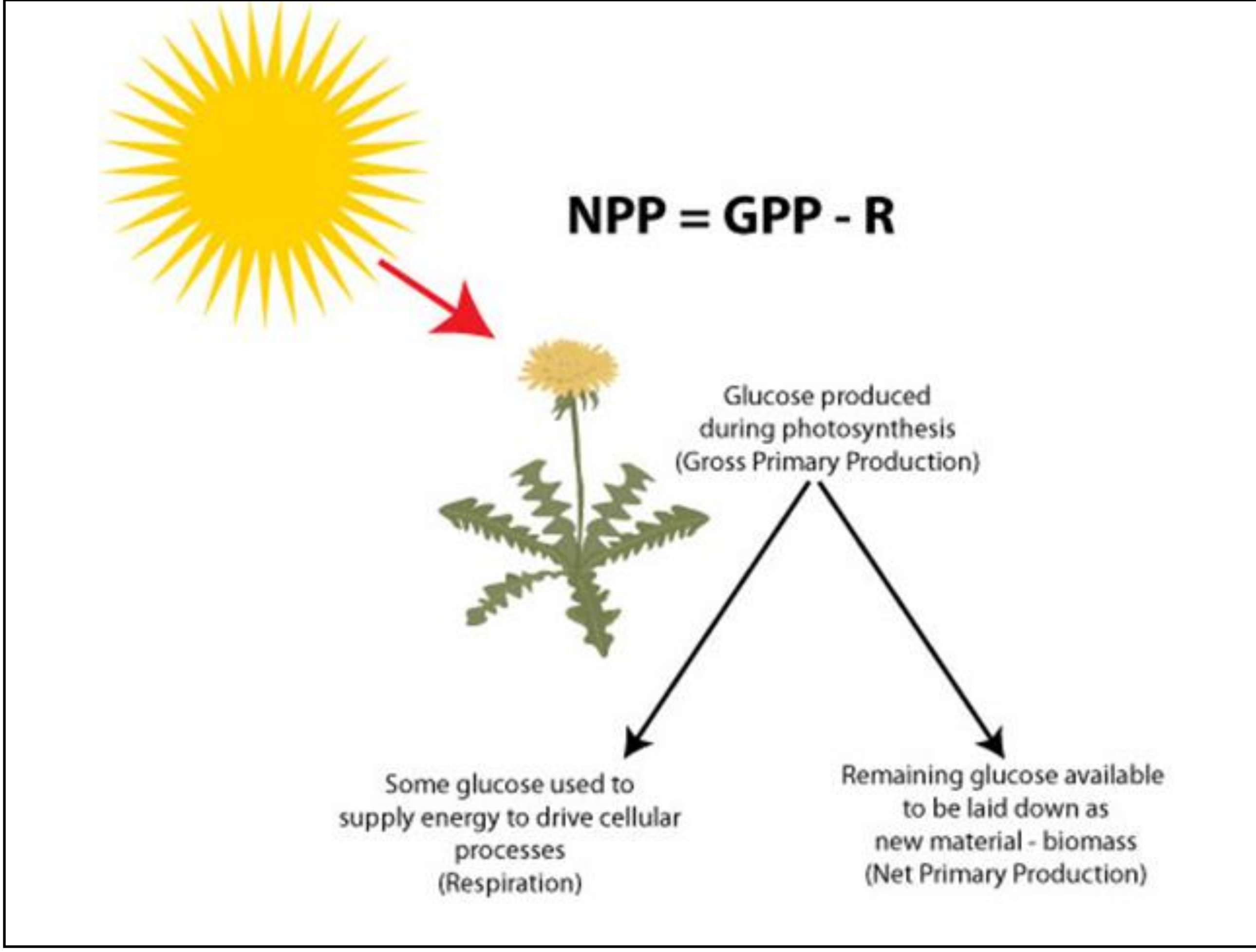
Interactions between organisms and their environments results in the movement of matter & energy

-***Energy flows through ecosystems***

-***Matter is recycled through ecosystems***

Primary Production

- Amount of solar energy converted into usable chemical energy in a time period.
- Predicts/Models the health of an ecosystem.
- Any change to primary productivity will lead to an amplified change in the rest of the ecosystem.



Producers: Produce chemical energy but also require it themselves for cellular respiration!

Gross PP = Total chemical energy produced

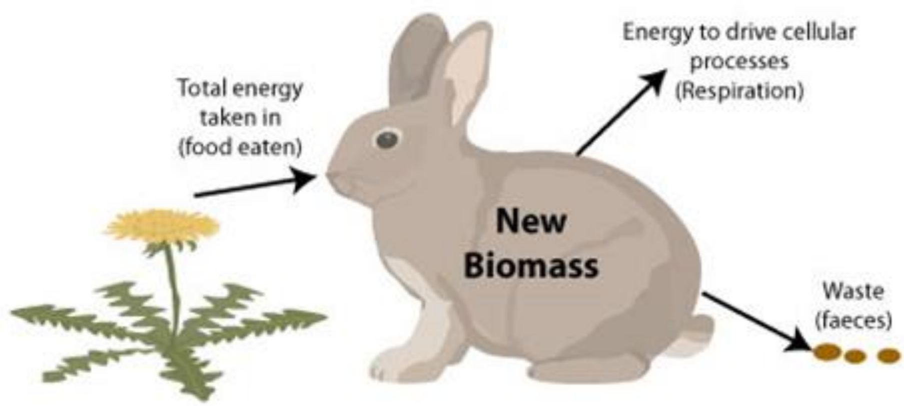
Net PP = GPP – R

Represents energy available to consumers and can be used to partially predict ‘K’ for a population

Secondary Production

Amount of consumers' food used towards their own body mass.

Transfers are usually less than 20% efficient.



Plant has 200 J energy

Caterpillar eats plant

100 J of plant cannot be metabolized and is elimintated.

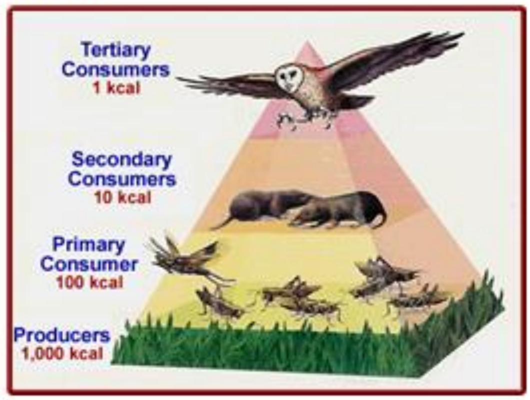
67 J is used for cellular respiration

This leaves 33 J (17%) energy contributing to the caterpillars body mass (growth).

Ecological Pyramids

1. Production Pyramid: Shows how much energy is in each trophic level.

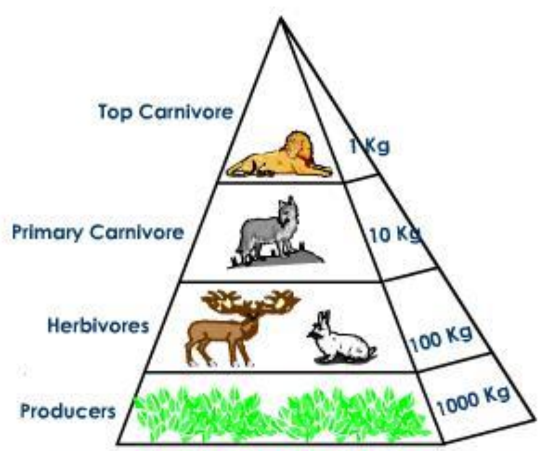
- About **10%** of **energy** in one trophic level is transferred to the next.



Ecological Pyramids

2. Biomass Pyramid: Shows the total amount of living material in a trophic level.

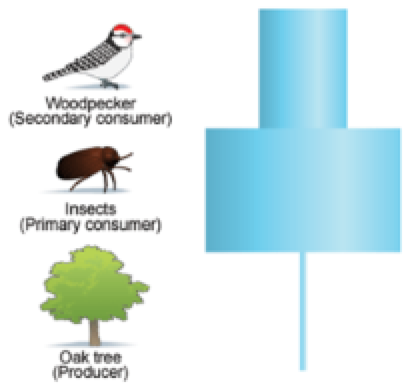
- Represents the potential amount of food for the next trophic level.



Upright Pyramid of biomass in a Terrestrial Ecosystem

Ecological Pyramids

3. Pyramid of Numbers: Shows how many individuals are in each level.



Explain the difference in appearance of this model with the other 2 and explain why the shape is different. Would the shape always be like this?